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## *Vineyard Irrigation*

by
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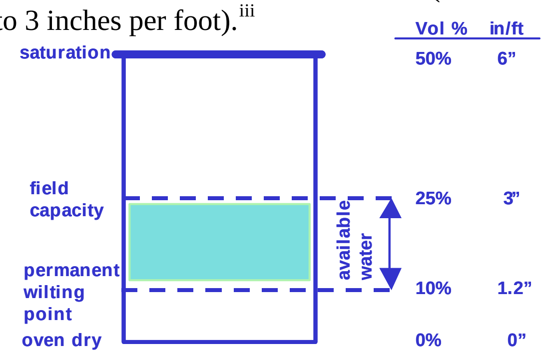
### Water and the Vine[i]

**Toward Quality Wine**—Quality wine derives in large part from quality grapes that, in turn, are harvested from healthy and balanced vines—vines that balance shoot and berry growth.

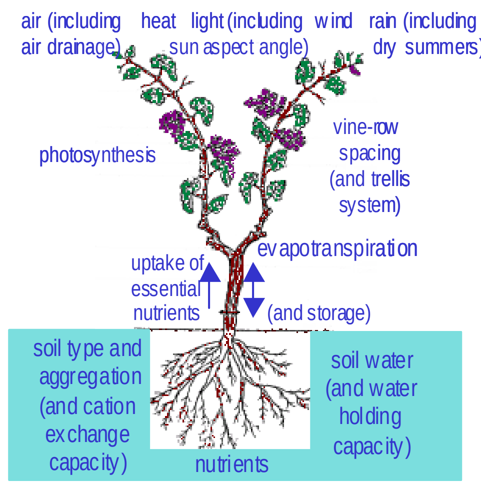
"Vine balance"[ii] is dependent on numerous factors including water in the soil that is taken up by the roots along with essential nutrients.

**Water Management**—Given strategic decisions (e.g., vineyard site with its location, climate, and soil; variety, clone, and rootstock; and trellis system), most winegrowers acknowledge that irrigation is one of the most critical variables under their control that has a significant impact on vine balance and grape quality. Management of soil moisture is important to quality grapes.

**Vine Available Water**—Vine available water equals field capacity minus permanent wilting point (VAW = FC - PWP) where water comprises from 10% to 25% of the soil volume (or from 1.2 to 3 inches per foot).[iii]




Vine available water is dependent in large part on soil typology, evapotranspiration, and water replenishment by rain or irrigation; VAW varies by soil, vine, spacing, weather, and other factors.




### Soil

**Soil Typology & Water**—Water enters the soil through rain, springs, dew, fog, irrigation (the subject of this paper), etc. It is stored in pores among soil particles for use by the vines and other plants having proximate root systems. The amount of water that can be stored and its effectiveness vis-à-vis vines is a function of:[iv]

- Soil profile—Individual soil layers called horizons:

  **A** horizon: Surface soil (or topsoil)

  **B** horizon: Subsoil (e.g., clay pan)

  **C** horizon: Parent material (e.g., alluvial)

- Soil texture—Soil is comprised of individual mineral particles whose diameter varies:

  Sand: Relatively large 2.0 - 0.05 mm

  Silt: Intermediate 0.05 - 0.002 mm

  Clay: Relatively small below 0.002 mm

  Water holding capacity is highest for clay.

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- Soil structure—Soil particles are normally arranged as aggregates of clay, silt, and sand (except for pure sand which may be relatively homogenous). There are four types of aggregates (granular is best for vines):

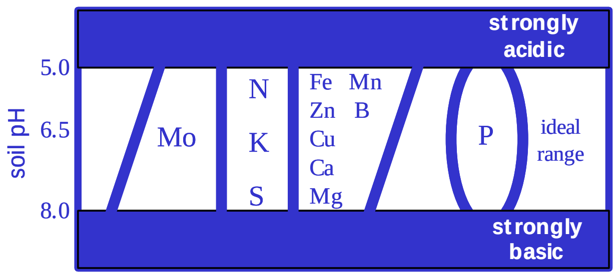
  Granular: Provides adequate porosity for water and air (as shown for soil moisture)

  Prismatic: Flat, vertical columns

  Blocky: Angular cubes

  Platy: Relatively flat vertical surfaces

- Soil reaction (pH)—Influences nutrient availability, solubility of toxic ions, and microbial activity. Nutrient availability varies by soil pH:




  The ideal pH is about 6.5.

- Cation exchange capacity—CEC is a measure of the fertility and potential productivity of a soil. Soils with high organic matter and clayey soils have higher CEC and, accordingly, potentially higher concentrations of calcium ($Ca^{++}$), magnesium ($Mg^{++}$), potassium ($K^{+}$), ammonium ($NH_4^{+}$), sodium ($Na^{+}$), and hydrogen ($H^{+}$).

  Typical CECs of some soil texture classes:

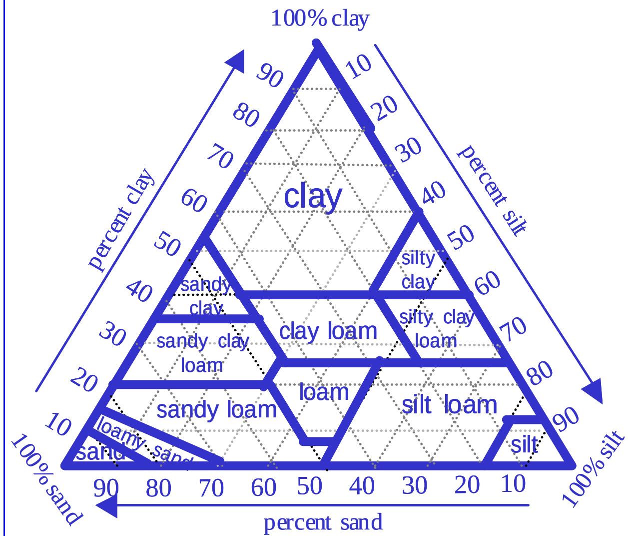
| soil texture | typical CEC range |
|---|---|
| | Meq/100 gms |
| Sand | 2 - 6 |
| Sandy Loam | 3 – 8 |
| Loam | 7 – 15 |
| Silt Loam | 10 – 18 |
| Clay and Clay Loam | 15- 30 |

- Soil organic matter—Improves soil tilth and structure, improves aeration and water infiltration, increases water-holding capacity, provides significant CEC, provides source of micronutrients and soil microorganisms such as bacteria and fungi. A gram of soil (about 1 cubic centimeter) may contain 4 million bacteria. "Cover cropping" can add organic matter to soil and improve soil aggregation.

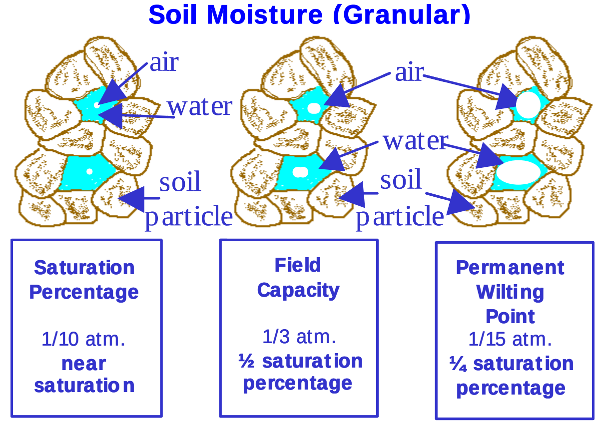
**soil** (soil) *n.* **1.** The top layer of the earth's surface, consisting of rock and mineral particles mixed with organic matter. **2.** A particular kind of earth or ground: *sandy soil.* **3.** Country; land: *native soil.* **4.** A place or condition favorable to growth; a breeding ground.

The American Heritage Dictionary

**Soil Texture**




**Soil Moisture (Granular)**




Source: For soil texture and moisture is *Western Fertilizer Handbook*, California Fertilizer Association (8th Ed. 1995)
http://vig.prenhall.com/catalog/academic/product/1,4096,0813432103,00.html

- Soil aggregation—Typically, soil is composed of 45% minerals, 5% organic matter, and 50% pores filled with air and water. Plus or minus!!
- Soil moisture—Water is held as a film around soil particles. After irrigation, we have near saturation. In a few days, water moves deeper into soil and we have field capacity. At the point that vines cannot extract water, we have reached the permanent wilting point.

| Annual Growth Cycle of Vine (from Dormancy to Dormancy) | | | |
|---|---|---|---|
| Buds go through stages (dormant, swelling, green tip, first leaf) with nutrients directed mostly to cell division. | Vegetative growth is dominant with transition to to fruit growth as version (berry ripening) begins. | Fruit growth is dominant with nutrients directed to cell enlargement. Berry º Brix (sugar) and pH increase, acid decreases. | After harvest, storage is dominant with starch (CHO) and nitrogen stored in the root system via the vine's phloem. |
| **Ideal Soil $H_2O$ Status FIELD CAPACITY** | **Ideal Soil $H_2O$ Status FIELD CAPACITY** | **FC then get close to PERM WILTING POINT** | **Ideal Soil $H_2O$ Status LESS IMPORTANT** |
| Water required for:<br>1 Mineral uptake<br>2 Turgor or pressure outward on cell walls drives cell enlargement<br>3 Evaporative cooling<br>4 Photsynthesis ($CO_2$ + $H_2O$ → sucrose + CHO)<br>5 Stomate functioning | Water required for:<br>1 Growth in apical meristem on shoot tip<br>2 Growth in root tip meristem<br>3 Secondary growth<br>4 Berry structural growth<br>5 New tissue for all of above | Water required for:<br>1 Berry cell enlargement<br>2 Fruit ripening<br>3 Fruit sucrose → glucose + fructose (moved in phloem)<br>4 º Brix goes up as sugar goes up **OR *if water goes down (stress)*** | Water required for:<br>1 Movement of CHO and N via phloem to roots for storage |

**Bud Break** — **Bloom** — **Veraison** — **Maturity (Harvest)** — **Leaf Fall**

Source: VWT 132 Soils, Fertilization, Irrigation, Viticulture and Winery Technology Program, Napa Valley College (Spring 1998)

## Water & Water Mechanisms

**Use of Water in the Vine**—As suggested above, vines require water throughout the growing season.

**Soil Type & Water Storage**—Soil type and many other factors contribute to wine quality. Many French are convinced that the key is *terroir*—the holistic combination of soil and topography interacting with each other and with macroclimate to determine mesoclimate and vine microclimate[v].

Some very fertile soils have an A horizon of over 8 to 10 feet that allows deep root penetration that facilitates storage of enough water to allow "dry" farming or, more correctly, non-irrigated farming.

At the other end of the spectrum, thin infertile soils with an A horizon of only 2 or so feet (and an impenetrable barrier in the B horizon) store only limited amounts water and usually require supplemental irrigation to maintain field capacity.

**Soil Texture & Water Storage**—The storage capacity of soil in inches of water held per foot of soil (and maximum rate of irrigation in inches per hour) varies from 0.05 - 0.07 inches/foot (0.75 inches/hour) for sand to 1.4 - 2.4 inches/foot (0.15 inches/hour) for clay.[vi] The need of a particular vine depends on specifics related to soil, vine spacing, evapotranspiration and related variables that can vary from plant to plant.

**Water Stress**—Water at the field capacity is useful except as maturity approaches when water stress can be safely induced while maintaining enough water for photosynthesis. If field capacity cannot be maintained, the result can be stunted shoot growth, underdeveloped berries, and undersupply of starch. Yet, some growers introduce stress before veraison to regulate over-active shoot growth of vigorous vines.

More commonly, as maturation approaches and a decrease in cell division can be tolerated, most viticulturists consider water stress beneficial to grape quality. This planned water stress moves the soil water from field capacity toward the permanent wilting point. Water stress slows—or even stops—shoot and root growth, causes leaf senescence (decline), affects leaf blade orientation (leaf edge rotates toward sun), apical meristem tendrils slow, and internode spacing shortens. Water stress should stop short of the PWP as photosynthesis would stop and cause leaf-edge stomates to close.

Irrigation strategies raise two questions:

1. When is water needed by vines?
2. How much water is needed?

Several techniques-*cum*-technologies exist to help winegrowers answer these two questions.

## Irrigation Practices & Techniques

| Strategic | Tactical/Operational |
|---|---|
| Site location (e.g., climate, soils, typology) | Practices |
| Site preparation (e.g., ripping) | Non-irrigated ("dry") farming |
| Soil augmentation (e.g., addition of lime) | Maintain field capacity |
| Development of water supplies (e.g., reservoir) | Regulated deficit irrigation |
| Installation of water delivery systems (e.g., drip irrigation) | Partial rootzone drying |
| Vine-row spacing (e.g., accommodate vine vigor) | Techniques |
| "Rootstock selection" (e.g., 101-14 for thin A horizons) | Visual vine or soil inspection |
| | Evapotranspiration |
| | Water budget method |
| | Neutron probe |
| | Di-electric constant |
| | Tensiometer |
| | Pressure chamber |

**Non-Irrigated ("Dry") Farming**—Employed when vine, soil, evapotranspiration, and other factors provide sufficient water without irrigation.

**Maintain Field Capacity**—Irrigate to maintain FC.

**Regulated Deficit Irrigation**—This is the most popular approach. Irrigation water can be applied when: (a) available water falls below a threshold, (b) the vines have slowed or stopped growth, or (c) a heat wave occurs. Water can be denied the vines when (d) over-vigorous shoot growth is experienced or (e) maturation is a few weeks off.

**Partial Rootzone Drying**—Irrigate half the roots of each vine while letting the other half dry out. After a few days, reverse the situation and irrigate the dry half of the roots while the irrigated part is allowed to dry out. May use underground drip.

**Visual Vine Inspection**—Observe: (a) stoppage or slowing of growth of the apical meristem, (b) shortened shoot internodal spacing, or (c) vine starts to get rid of leaf surface by shedding old leaves first (grapevines do not wilt).

**Visual Soil Inspection**—Estimate water availability from soil samples taken near vines (use tube, auger, digging) and test as follows:

Above FC: Free water seen, easily squeezed out.

100% FC—Upon squeezing, wet outline of ball is left on hand.

75-100% FC: Forms weak ball for sandy soils, very pliable ball for silty soils, and ribbons out between fingers for clayey soils.

50-75% FC: Dry or breakable for sand, pliable ball for silt, and ribbons out for clay.

25-50 % FC: Dry for sand, crumbly for silt, pliable ball for clay.

0-25%FC (0% is PWP): Dry and loose for sand, dry and crusted for silt, hard baked for clay.

**Evapotranspiration (ET)**—Calculate or look up evapotranspiration values and add enough water to make up for loss. Evapotranspiration is the water lost to the atmosphere by evaporation and transpiration. Factors include net solar radiation, wind speed, density and type of vegetative cover, availability of soil moisture, root depth, reflective land-surface characteristics, and season of year.

For example, the calculated vineyard water use in Napa Valley between budbreak (4/3/02) and harvest (9/2/03) for a Cabernet vineyard using a VSP trellis and a six-foot row middles, was 17.7" and applied water was 89% of that value (15.8"). Potential ET for the same timeframe was 34.4".[vii]

**Water Budget Method**—Uses ET estimates to track water deficit until a "management allowable depletion" is reached and water is added to soil.

**Neutron Probe**—Given proper calibration, allows rapid and repeatable measurement of total soil water content at several depths and locations in a vineyard by determining the amount of hydrogen in the soil.

**Di-electric Constant**—Uses reflectrometry (propagation of high-frequency electromagnetic waves) to measure time to move between two probes, the faster the time, the lower soil moisture.

**Tensiometer**—Measures how tightly soil moisture is held by soil particles.

**Pressure Chamber**—Measures water potential in a leaf with soil moisture deficits related to the water status of the vine and its leaf.

## Irrigation Matters

Winegrowers agree that irrigation is the most important management practice for quality wine grape production known to directly effect fruit acidity, pH, and phenolics, including anthocyanins in red grape berries.[viii]

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i This paper is based in part on the Soils, Fertilization, and Irrigation class at Napa Valley College

ii Click on titles (in quotes, blue, underlined) of papers at: http://www.shilohestate.com/se_svwknowledgebase.htm

iii T. Prichard: http://ucce.ucdavis.edu/files/filelibrary/40/975.pdf

iv *Western Fertilizer Handbook*, California Fertilizer Association (8th Edition 1995)

v Oxford Companion to Wine, Jancis Robinson, ed. (1994)

vi op cit *Western Fertilizer Handbook*

vii "Irrigation of Winegrapes in California" by L.E. Williams at: http://www.practicalvineyard.com/novdec01p42.htm

viii Stan Grant, "Promoting Fruit Quality and Vine Health," *Practical Winery & Vineyard* (May/June 2000)